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Internal combustion engine with external supercharging

The invention relates to an internal combustion engine with a combustion chamber, inlet and outlet valves to the chamber and supercharging of the admitted fresh air, characterized in that an external compressor undertaking the major part of the compression of the engine and inlet valves, which close off the supply of the compressed air or of the completed fuel/air mixture shortly before or at the top dead center position of the piston, are provided.

Description

The invention relates to an internal combustion engine, in which the necessary compression of the entering fresh air principally takes place outside the cylinder by means of a compressor, such that merely a secondary compression takes place inside the cylinder.

The necessary preparation of the compressed fresh air for a combustion process can take place in various ways. For example, in the case of a normally aspirated engine, the external air is sucked into the cylinder via the opened inlet valve due to the low air pressure created by the downward motion of the piston and then compressed during the subsequent upward movement of the piston. In this case the compression of the air/fuel mixture takes place exclusively by means of the piston compression.

In order then to achieve an increase in the performance of the internal combustion engine, fresh supercharged air is admitted to the combustion chamber by increasing the intake air pressure above that of the external air pressure. The increase in charge pressure is achieved via a combination of exhaust gas turbine and supercharger, in such a way that first the energy contained in the exhaust gas is converted into mechanical energy by the exhaust gas turbine and then the pressure of the charge air is increased using the common shaft of the exhaust gas turbine and the supercharger.

Although this type of supercharging does on the one hand increase the power, on the other hand the overall efficiency is reduced because the efficiency of the exhaust gas supercharger has to be taken into account. Therefore this type of supercharging is seldom used on engines in commercial use, but rather on sports and racing engines. Also, only supercharging in the full load power range is of practical application because in the partial load range throttling is always necessary. Since, in addition, when the charge air is compressed the tendency towards detonation during combustion increases, charge air cooling has to be incorporated, which in turn further reduces the efficiency.

A device for providing a fuel mixture, in particular a carburettor, to which the fuel is fed under pressure, is known from DE-PS 8 66 873. This involves the insertion of a valve in the fuel line, which is controlled by an appropriate component with respect to the pressure in the fuel line and the air pressure in the induction line.

Overall, it can be established that the combination of an exhaust gas turbocharger and the conventional internal combustion engine represents a combination of preliminary supercharging in the supercharger and a single-stage secondary compression in the cylinder, in which the proportion of pre-compression in the supercharger is small relative to the secondary compression in the cylinder. This further single-stage compression by the piston, which takes place in spite of the pre-compression by the exhaust gas turbocharger, therefore leads to an uneconomic overall process.

An internal combustion engine is known from DE-OS 24 10 948, in which the combustion air is subjected to an approximately isothermal compression process and is subsequently heated by the hot exhaust gases. In this process a part of the compressed hot air is branched off for carburetion, preheating and/or compression of the fuel and the combustion air and the combustible gas that is formed are separately fed in approximately stoichiometric amounts to a burner nozzle, mixed therein and burnt through auto-ignition with only minimal excess of air and without increase in pressure. A disadvantage in this process is that combustion without increase in pressure is sought and complicated measures are required to achieve it.

The object of this invention is to achieve an improvement in overall efficiency. This is obtained by moving the work of compression from the actual cylinder to a compressor situated in the fresh air feed.

By this means, instead of the single-stage piston compression, a controllable, multi-stage compression is possible by using an external compressor.

In order to achieve a more economical compression of the charge air relative to the single-stage piston compression, the external compressor can take the form of a multi-stage compressor. Ideally, a compression process should take place after an isothermal change of state, i.e. the increase in pressure and the decrease in volume should take place at constant temperature. However, an isothermal compression can be achieved only if the work done during compression is dissipated as heat, i.e. the machine must be cooled. Frequently only incomplete cooling of the compressor is achieved by means of small heat transfer surfaces and fast speeds. In these cases the compression approximates more an adiabatic change of state because practically no heat energy is exchanged with the surroundings during the compression process.

A reduction in the additional adiabatic work that arises can be achieved by stepwise compression with intermediate cooling.

This will be explained in greater detail on the basis of a two-stage air compression process. In the first stage the air is compressed adiabatically from the initial pressure to the intermediate pressure. In so doing the temperature increases. The air is then cooled at an almost constant intermediate pressure in the intermediate cooler; in the ideal case back to the initial temperature. In the second stage an adiabatic compression again takes place, from the intermediate pressure to the final pressure. Thus the isothermal process can be approximated by using a multi-stage compression, with intermediate cooling and with increasing sub-division of the compression processes.

Apart from the decrease in the additional adiabatic work for the complete compression process, two-stage or multi-stage compression with intermediate cooling offers the advantage of a lowering of the final temperature of the air. For the multi-stage compressor the work requirement is at a minimum when the selected pressure ratio is the same in all the stages.

The described advantages of the multi-stage compression can be used to avoid the disadvantages of the single-stage piston compression process if the largest part of the compression work for the internal combustion engine is taken over by an external compressor.

This concept can be applied to the Otto cycle engine and also to the Diesel cycle engine. In the case of the use of multi-stage compression there is a further advantage that the air/fuel mixture for the combustion process can be fed to the engine at a lower temperature (approx. 50% lower), so that the demands on the fuel can be reduced, such as in the sense of lower octane rating and the avoidance of additives.

The achievable improvement in efficiency due to the 'colder' supply and higher compression is in the range of 5% – 7% in full load operation and up to 30% is possible in the partial load range. The level of compression can be matched here to the respective loading condition by controlling the compressor.

The high thermal loading of the engine that arises at high compression during the combustion process can be reduced by means of internal cooling, such as water injection in the combustion chamber *i*, which also results in a gain in the expansion work.

Today's compressors, in particular modern rotary and screw type compressors, have become so small and performance-capable that they can be housed together with a normal internal combustion engine in a conventional motor vehicle.

Additional features and advantages are given in the dependent claims and in the following description of examples of embodiments of the invention which are represented in the drawings.

The drawings show the following:

Fig. 1 The use of multi-stage compression for charging the cylinders of Otto engine

Fig. 2 The use of multi-stage compression for charging the cylinders of a Diesel engine.

Fig. 3 A valve arrangement for regulating the overall level of compression.

Fig. 1 shows a principle for the arrangement of an Otto process. The arrangement comprises a multi-stage compressor (2), a fuel/air mixing device (3), a piston stroke device (5) and an exhaust gas outlet (4).

The conventional sequence cycle of an Otto engine in accordance with the two-stroke or four-stroke cycle is changed in that the inlet valve for the fuel/air mixture remains open until just before the point in time at which the piston has reached the top dead center (TDC) and the mixture is ignited. The desired compression is provided by the compressor (2) through suction in of the fresh air (1) and the following multi-stage compression.

Thus the total compression work is transferred from the uneconomical single-stage compression by a piston to the more economic multi-stage compression provided by the compressor (2). By modifying the compression the output of the engine can also be varied as appropriate. In the partial load range the cylinder charging can be stopped completely and the engine can be operated at "idle". In addition, by means of a time-wise displacement of the point at which the inlet valve opens relative to the cylinder charging with the already compressed fuel/air mixture, a combination of external compression and internal piston compression can be obtained. The external preparation of the mixture, which is characteristic of the Otto cycle, can in this way take place by means of a conventional carburettor or injection system.

Fig. 2 shows a corresponding illustration of the principle of the arrangement of the Diesel cycle. Here the arrangement comprises a multi-stage compressor

(2'), a heating device (3'), an exhaust gas outlet (4') and a fuel feed (5'). In the Diesel cycle this is provided by an internal mixing, in contrast to the external mixing in the Otto cycle. The fuel/air mixture that results is ignited in the highly compressed hot air.

The compression of the inducted fresh air (1') likewise takes place as in the case of the Otto cycle described above, via a multi-stage compression through the compressor (2'). In order to achieve the necessary process temperature for the auto-ignition, the compressed fresh air is heated by the hot exhaust gas prior to the charging of the cylinder. The cylinder is charged via the open inlet valve with the heated and already compressed air. At the TDC of the piston movement the fuel is mixed in the cylinder via an injection pump and the ensuing explosion of the mixture initiates the downward motion of the piston. During the warm-up period of the Diesel engine the compressed air must be heated up by an external source of heating.

Thus, in the case of the Diesel cycle as well, the necessary compression work can take place by means of an external compressor and the efficiency of the overall arrangement can be improved in this way.

Fig. 3 shows a valve arrangement in the combustion chamber for the case of a four-stroke engine, which enables the cylinder to be charged with compressed air and, if desired, a combination of pre-compression by the external compressor and a secondary compression in the cylinder. The valve arrangement in this case consists of an outlet valve (6), an injector valve/inlet valve (7) and a compensation valve (8). The outlet valve (6) functions in the same way as a 'conventional' outlet valve, which by opening the outlet cross-section at the end of the expansion stroke, enables the combustion gases to flow out of the cylinder.

The actual charging of the cylinder with compressed air or fuel/air mixture takes place via the injector valve (7). The injector valve (7) opens after the closing of the compensation valve (8). By means of a time-shift of the valve timing cycle

(opening/closing) relative to the piston movement an additional secondary compression can take place in the cylinder. For example, a high secondary compression can be achieved by an early opening/early closing, while with a late opening/late closing practically no secondary compression occurs. In this case the secondary compression is practically the same as the pre-compression, which is given by the level of compression of the compressor.

The compensation valve (8) is provided to avoid low air pressure and unwanted compression in the cylinder. It opens like a “conventional” inlet valve and closes before the opening of the injector valve (7).

An additional effect caused by this compensation valve is cooling brought about by the surrounding air.

Patent claims

1. An internal combustion engine with a combustion chamber, inlet and outlet valves in the chamber and charging through the fresh air inlet, **characterized in that** an external compressor (2, 2') is provided, which takes over the major part of the compression of the engine and an inlet valve or valves (7), which closes/close off the admission of compressed fresh air or the admission of the completed fuel/air mixture shortly before or at the piston top dead center.

2. The internal combustion engine according to Claim 1, characterized in that the compressor (2, 2') is formed as a multi-stage rotary compressor.

3. The internal combustion engine according to Claim 1 or Claim 2, characterized in that an additional compensation valve (8) is fitted.

4. A method of supercharging for an internal combustion engine, in which the gas exchange takes place with supercharged fresh air, characterized in that a compressor (2), connected upstream of the cylinder with the piston, compresses the inducted fresh air (1) in such a way that the piston (5) is only required to undertake a small proportion of the compression work.

5. The method of supercharging for an internal combustion engine according to Claim 4, characterized in that the mixing of the fresh air (1), which is sucked in and compressed by the compressor (2), and fuel (3), takes place outside the combustion chamber.

6. The method of supercharging for an internal combustion engine according to Claim 4, characterized in that that the mixing of the fresh air (1'), which is sucked in and compressed by the compressor (2'), and fuel (5'), takes place inside the combustion chamber, in which before the gas

exchange the compressed fresh air (1') is heated by the exhaust gas and then fed to the combustion chamber.

7. The method of supercharging for an internal combustion engine according to Claim 4, characterized in that the compression process is a multi-stage operation that takes place in the compressor (2, 2').

8. The method of supercharging for an internal combustion engine according to Claim 4, characterized in that the gas exchange of the combustion chamber is controlled via an outlet valve (6), an injector valve (7) and a compensation valve (8).

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